

*EMERGENT STIMULUS RELATIONS DEPEND ON STIMULUS CORRELATION AND NOT ON REINFORCEMENT CONTINGENCIES*SARA TEPAERU MINSTER<sup>1,2</sup>, DOUGLAS ELLIFFE<sup>1</sup>, AND SURESH D. MUTHUKUMARASWAMY<sup>3</sup><sup>1</sup>THE UNIVERSITY OF AUCKLAND<sup>2</sup>THE BRAIN REPAIR GROUP, SCHOOL OF BIOSCIENCES, CARDIFF UNIVERSITY<sup>3</sup>CUBRIC, DEPARTMENT OF PSYCHOLOGY, CARDIFF UNIVERSITY

We aimed to investigate whether novel stimulus relations would emerge from stimulus correlations when those relations explicitly conflicted with reinforced relations. In a symbolic matching-to-sample task using kanji characters as stimuli, we arranged class-specific incorrect comparison stimuli in each of three classes. After presenting either Ax or Cx stimuli as samples, choices of Bx were reinforced and choices of Gx or Hx were not. Tests for symmetry, and combined symmetry and transitivity, showed the emergence of three 3-member (AxBxCx) stimulus classes in 5 of 5 human participants. Subsequent tests for all possible emergent relations between Ax, Bx, Cx and the class-specific incorrect comparisons Gx and Hx showed that these relations emerged for 4 of 5 the participants after extended overtraining of the baseline relations. These emergent relations must have been based on stimulus–stimulus correlations, and were not properties of the trained discriminated operants, because they required control by relations explicitly extinguished during training. This result supports theoretical accounts of emergent relations that emphasize stimulus correlation over operant contingencies.

*Key words:* stimulus equivalence, emergent relations, stimulus correlation, mouse-click, humans

The emergence of novel stimulus functions has interested behavior analysts since our field's infancy (e.g., Hull, 1939). How is it that functions emerge with respect to stimuli that have never before evoked, or been trained to evoke, such functions? This is particularly a problem when we consider emergent functions that cannot be explained by stimulus generalization, or the physical similarity between trained and test stimuli. The work of Sidman and colleagues (e.g., Sidman, 1971; Sidman & Cresson, 1973; Sidman & Tailby, 1982) regenerated interest in stimulus equivalence of this kind and we have recently seen a rapid proliferation of experiments designed to uncover the conditions that are sufficient for the emergence of novel stimulus functions. Theoretical accounts have developed in parallel, and there is now much division between

behavior analysts as to how we might best account for the increasingly complex behaviors demonstrated in experiments investigating emergent stimulus functions.

Relational frame theorists (RFT: e.g., S. Hayes, 1991; S. Hayes, Barnes-Holmes, & Roche, 2001) have argued that responding in situations in which novel stimulus functions emerge is due to the arbitrary application of generalized operant classes defined by certain properties of mutual and combinatorial entailment, and the transformation of functions. Sidman (2000) argued that equivalence relations, defined as emergent relations between at least three stimuli that satisfy the properties of reflexivity (if A then A), symmetry (if AB then BA), and transitivity (if AB and BC then AC), are a previously unknown outcome of reinforcement contingencies and a fundamental property of the conditional discriminated operant. In contrast, L. Hayes (1992) argued that stimulus-pairing associations are sufficient to account for Sidman-type equivalence relations. Similarly, Tonneau (2001, 2002) has suggested that stimulus pairings, or correlations, work independently of operant reinforcement contingencies to produce emergent stimulus functions and function transfer.

For our purposes here, the critical difference between these two groups of theorists is that both RFT and Sidman emphasize the role

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of operant reinforcement contingencies, whereas L. Hayes and Tonneau emphasize stimulus pairing, often described as “respondent-type” relations. The relative importance of each contingency has received some empirical attention, and the recent trend is towards increasing recognition of the importance of stimulus pairing. There is a body of literature demonstrating the emergence of common stimulus functions (i.e., conditional behavioral relations), function transfer, and function transformation in procedures that have no programmed reinforcement contingencies, but instead rely on environmental correlations between stimuli, and in some cases a history of conditional responding also. Procedures relying on environmental correlations include respondent-type stimulus pairings (e.g., Leader, Barnes & Smeets, 1996; Leader, Barnes-Holmes & Smeets, 2000; Smeets, Leader, & Barnes, 1997). This procedure has also been called the stimulus pairing observation procedure (SPOP: e.g., Smyth, Barnes-Holmes & Forsyth, 2006). Such experiments have shown that environmental stimulus correlations, alone, are sufficient to induce the emergence of common functions between correlated stimuli. The multiple negative comparisons procedure (e.g., Harrison & Green, 1990), which arranges a perfect correlation between a given sample and comparison stimulus, and a less-than-perfect correlation between the same sample and other comparisons, is also enough to produce the common emergent stimulus functions.

Environmental stimulus correlations are also a sufficient condition for the transfer of additional response functions. For example, Tonneau and González (2004) demonstrated the transfer of key-press response functions among stimuli between which there was a consistent environmental correlation. Furthermore, environmental stimulus correlations have recently been shown to be a sufficient precursor for function transformation. Tonneau, Arreola, and Martínez (2006, Experiment 2) showed that pairing contexts (locations on a computer screen) with established relations of “same” and “different” transformed the functions of arbitrary stimuli that were later presented in those contexts, in accordance with the relations paired with each context. These effects were shown in the absence of response requirements during the

pairing phases, and in the absence of reinforcement.

Another procedure that shows the effect of environmental stimulus correlations is the presentation of stimuli as elements of a complex, multielement stimulus (e.g., Markham & Dougher, 1993; Markham, Dougher, & Augustson, 2002; Schenk, 1993, 1995; Smeets & Striefel, 1994; Stromer, McIlvane, Dube, & Mackay, 1993; Stromer, McIlvane & Serna, 1993). For example, Markham *et al.* taught adults conditional relations between nine complex AB samples and three singular C stimuli. They then trained an ordinal sequencing task (Experiment 1) and respondent elicitation functions (Experiment 2) to singular A stimuli. Both transferred to BC compounds, showing emergent transfer of functions between stimuli that had not been paired through reinforcement contingencies, but only through spatiotemporal contiguity. This emphasizes the point that reinforcement contingencies are not necessary to produce equivalence-related phenomena such as the transfer of function.

A participant with a history of learning conditional discriminations in which response-contingent feedback is delivered may, on novel conditional discrimination tasks, demonstrate the consistent conditional selection of comparison stimuli immediately on the introduction of those novel tasks, and in the absence of any feedback or reinforcement for comparison selection. This finding has been referred to as the unreinforced conditional selection of comparison stimuli (Saunders, Saunders, Kirby, & Spradlin, 1988). In this case, stimuli participating in the unreinforced matching relations simply had to be presented in the same spatiotemporal arrangement as the stimuli of previously established conditional discriminations for the emergence of common functions between these stimuli (e.g., Saunders *et al.*, 1988; Williams, Saunders, Saunders, & Spradlin, 1995). This outcome has also been observed with the higher-order stimuli of contextually controlled conditional discriminations (Serna & Pérez-González, 2003) where stimuli presented in the same spatiotemporal position as previous higher-order functioning stimuli showed the emergence of the same class-altering functions as previously established second-order conditional stimuli.

With a growing literature documenting that reinforcement is not a necessary condition for the emergence of common stimulus functions, and recent evidence failing to support Sidman's (2000) operant-based account of stimulus equivalence with regard to reinforcer inclusion in multiple stimulus classes (Minster, Jones, Elliffe, & Muthukumaraswamy, 2006), we then asked the following question: Can stimulus pairings, or environmental stimulus correlations, provide the prerequisites for the emergence of novel stimulus relations when emission of those stimulus relations has always been placed under extinction by the operating reinforcement contingencies? That is, could stimulus correlations work independently of the reinforcement contingencies to result in the emergence of new stimulus relations that are *opposite* to those specified by the reinforcement contingencies?

There is evidence to suggest that such stimulus relations may emerge. Smeets, Barnes-Holmes, and Nagle (2000) showed that temporal contiguity between stimuli with different discriminative functions was sufficient to produce behavioral matching relations between those stimuli. Participants were trained on four simultaneous discriminations;  $A1^+/B1^-$ ,  $B1^+/C1^-$ ,  $A2^+/B2^-$ ,  $B2^+/C2^-$ . They were then given matching-to-sample tests for the formation of two equivalence classes,  $A1B1C1$  and  $A2B2C2$ , where, for example,  $C1$  was presented as a sample, and  $A1$  and  $A2$  were presented as comparisons. Participants matched  $A1$ ,  $B1$  and  $C1$  to one another, and  $A2$ ,  $B2$  and  $C2$  to one another, though most required reexposure to the initial simple discriminations in order to meet the criterion of 4/4 correct for each relation. A transfer of functions test again confirmed the formation of equivalence classes from the initial discrimination training, where a "clap" response trained to  $A1$  transferred to  $B1$  and  $C1$ , and a "wave" response trained to  $A2$  transferred to  $B2$  and  $C2$ . These data therefore showed that stimuli need not have the same discriminative function for conditional relations to emerge between those stimuli. Instead, temporal contiguity was sufficient to produce emergent conditional relations between contiguous stimuli.

The present experiment extends previous demonstrations of the emergence of shared function in the absence of reinforcement because the emission of the stimulus-stimulus

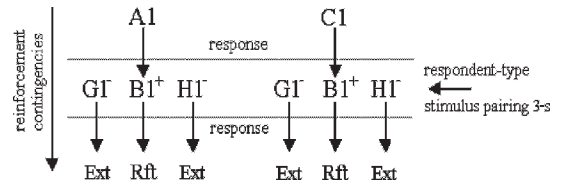


Fig. 1. Schematic diagram showing the baseline A-B and C-B conditional discriminations for Class 1 (procedures were similar for Classes 2 and 3). On these trials, the correct comparison,  $B1$ , was always presented with class-specific incorrect comparisons,  $G1$  and  $H1$ . Responding to  $B1$  was reinforced while responding to  $G1$  and  $H1$  was never reinforced. The stimulus pairing of 3 s occurred at comparison presentation where the choice response was completion of a fixed interval 3-s requirement. A response made to any comparison before 3 s had elapsed had no effect.

matching relations predicted to emerge due to stimulus correlations was given a consistent history of operant extinction during training. Thus, the reinforcement contingencies specified a participant *not make* a given correlation-based relation, while the correlations specified a participant *to make* that same relation. In this sense, the possible emergent relations based on history of operant contingencies and on stimulus correlations directly conflicted with each other. To do this, we used a hybrid procedure that arranged both operant reinforcement contingencies and environmental stimulus correlations. Stimulus correlations were set up by arranging class-specific incorrect comparisons (Figure 1). Baseline relations were trained using a many-to-one arrangement ( $Ax-Bx$ ,  $Cx-Bx$ ), but the procedure differed from typical matching-to-sample arrangements in that the incorrect comparisons for a particular class only ever functioned as  $S^-$  stimuli for that class—they were never  $S^+$  stimuli in a different class. This is unlike typical matching-to-sample procedures where comparison stimuli are both  $S^+$  and  $S^-$  depending on the sample stimulus. That is, our procedure was not a conditional discrimination in the usual sense. Having class-specific incorrect comparisons therefore meant that a perfect stimulus-stimulus correlation could be established between stimuli to be related according to the reinforcement contingencies (e.g.,  $A1$ ,  $B1$ , &  $C1$ ), and the incorrect stimuli to which those stimuli were not to be related according to the reinforcement contingencies (e.g.,  $G1$  &  $H1$ ). Also,

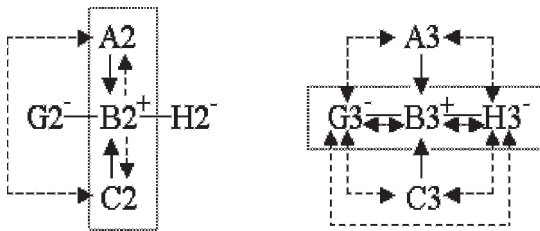


Fig. 2. Schematic diagram showing examples of the intended stimulus classes based on comparison-stimulus pairings. Relations explicitly trained with reinforcement contingencies are indicated by the solid arrows. The comparison-stimulus pairings implemented at the comparison-choice phase are indicated by the solid lines. Derived relations are indicated by broken arrows. An example of the equivalence classes predicted to emerge based on operant reinforcement contingencies is shown on the Class 2 stimuli (left diagram). The derived B-A, B-C, A-C, and C-A relations are shown with the broken arrows. Examples of the relations predicted to occur based on the comparison-stimulus pairings are shown on the Class 3 stimuli (right diagram). The derived A-G, A-H, B-G, B-H, C-G, C-H, G-A, G-B, G-C, G-H, H-A, H-B, and H-C relations are shown with the broken arrows.

these environmental relations were the only relations including Gx and Hx, unlike standard matching-to-sample tasks where comparisons participate in environmental relations with both reinforcement-contingency-related stimuli (e.g., environmental relations between sample and correct comparison), and with no-reinforcement-contingency-related stimuli (e.g., environmental relations between the correct comparison and the incorrect comparisons, and between the sample and the incorrect comparisons). That is, responses to Gx and Hx stimuli were never reinforced. The stimulus correlations were strengthened by imposing a 3-s stimulus pairing at the comparison choice phase (i.e., the choice response was completion of a fixed interval 3-s requirement). In this manner, the stimulus classes intended to be established through environmental stimulus correlations were designed to conflict with the stimulus classes intended to be established with reinforcement contingencies.

Figure 2 outlines the trained relations with Class 2 and Class 3 stimuli, and the emergent relations predicted to result from operant reinforcement, and environmental stimulus correlations, respectively. The prerequisite relations for three stimulus classes were trained as shown in Figures 1 and 2 such that each stimulus class had specific incorrect comparisons. The programmed reinforcement

contingencies were expected to establish three classes, A1B1C1, A2B2C2, and A3B3C3, an example of which is shown for the Class 2 stimuli. Maintenance of baseline trials would demonstrate class separation of positive and negative contingency elements. Emergence of equivalent stimulus-stimulus relations, shown on the Class 2 stimuli in the left panel of Figure 2, would demonstrate class formation, or in other words, a common stimulus function between Ax, Bx, and Cx. However, the programmed stimulus correlations were predicted to establish three classes, B1G1H1, B2G2H2, and B3G3H3, shown on the Class 3 stimuli in the right panel of Figure 2. In these predicted stimulus classes, a common function between positive and negative elements of the reinforcement contingency would therefore be established that would be at odds with the classes resulting from the reinforcement contingencies. The patterns of stimulus relations that would occur based on these predicted stimulus classes (BxGxHx) are shown on the Class 3 stimuli of Figure 2.

We therefore sought to investigate whether stimulus classes based on stimulus correlations could emerge even when those classes had a complete history of extinction according to the reinforcement contingencies. If class formation was observed that was in accordance with the predicted stimulus relations based on stimulus correlations, this would demonstrate an independence of the effects of stimulus-stimulus correlations from correlations involving reinforcers, on stimulus class formation. Such a finding would provide stronger support for the idea that shared stimulus function arising from operant reinforcement contingencies is not a necessary condition for the observation of emergent shared functions that indicate class formation, and further, would suggest that stimulus correlations might be the fundamental variable affecting stimulus class formation.

A pilot study was run in which participants were exposed to two experimental sessions; the first involved baseline training and tests for equivalence classes based on the reinforcement contingencies, and the second involved overtraining of the baseline relations followed by tests for the emergence of relations based on the correlations involving class-specific incorrect comparisons. Some, but not most, of these participants showed the emergence of



consistent matching relations involving S<sup>-</sup> stimuli. Because of the equivocal data produced by the pilot participants, we arranged additional overtraining of the baseline relations. Sutherland and Holgate (1966) found that rats trained to discriminate between a black horizontal rectangle and a white vertical rectangle typically showed overshadowing where control by the color dimension overshadowed control by line orientation. When the rats were overtrained (i.e., given more discrimination training after a mastery criterion had been met), control by the weaker dimension (line orientation) eventually emerged. In the present experiment, because responding to Gx and Hx stimuli is explicitly not reinforced, and under conditions of extinction, control by any relations involving these stimuli may be overshadowed by control from stimuli to which responding is explicitly reinforced (Bx). Given evidence that overtraining is one way to induce control by weaker stimulus dimensions, we speculated that overtraining might similarly overcome any overshadowing of the stimulus-stimulus relations by the strong operant contingency. The first session trained baseline relations and tested these baseline matching relations for the properties of equivalence. The second session overtrained the baseline relations. The third session continued with overtraining and then presented tests for the emergence of common stimulus functions based on the environmental stimulus correlations.

## METHOD

### *Participants*

Five undergraduate psychology students, 2 men and 3 women, served as participants and were numbered Q1 to Q5. They were not familiar with stimulus equivalence research, had never participated in experiments involving conditional discriminations, and had no prior experience with Japanese kanji characters.

### *Apparatus*

Participants sat at a table that supported a standard computer mouse and a computer monitor measuring 228 mm high and 306 mm wide, on which all stimuli were displayed. All responses were made via the left button of a

computer mouse. Stimulus presentation and data collection were controlled by an IBM-PC<sup>®</sup>-compatible computer running customized software programmed in Delphi5<sup>®</sup>. The computer recorded the identity and position of all stimuli and the choice response emitted on each trial, together with the time of all experimental events.

### *Stimuli*

Figure 3 shows the stimuli used as samples and comparisons. Each stimulus was contained within an area 160 pixels high and 150 pixels wide. Feedback stimuli were of the same dimensions. The samples and comparisons were black Japanese kanji characters on a white background. The feedback for correct responding consisted of the words "Correct!" and underneath "Click for the next trial". The incorrect feedback stimulus was "That was incorrect" and underneath "Click for the next trial". Feedback text was black, written on a white background. Feedback text was surrounded by a 10-pixel wide border that was blue for correct responses, and green for incorrect responses. Feedback stimuli appeared at the center of the screen. Sample stimuli were presented 130 mm from either side of the screen and 54 mm from the top of the screen. Three comparison stimuli per trial were presented in a horizontal row underneath the sample stimulus, and were centered, 41 mm from either side of the screen, 45 mm apart, and 52 mm from the bottom of the screen.

### *Procedure*

*Session structure.* The experiment was divided into three sessions. The first session arranged training on the prerequisite conditional discriminations for three equivalence classes (Part 1), removal of feedback on baseline trials (Part 2), and tests for equivalence relations (Part 3). The first session lasted about 1 to 1.5 hr. The second session aimed to overtrain the baseline relations and involved 10 blocks of Part 1 baseline relations presented with feedback (Part 4). The second session lasted about 45 min. The final session continued overtraining, and began with five blocks of Part 4 baseline trials with feedback, followed by a block of Part 5 baseline trials without feedback. Part 6 tests for relations based on stimulus pairings were then introduced. This

	A	B	C	G	H
Class 1	南	建	様	地	客
Class 2	哲	験	室	安	除
Class 3	試	震	寝	脳	掃

Fig. 3. Training stimuli for all potential stimulus classes.

final session lasted about 1 hr. Participant Q2 completed all sessions on the same day. Participants Q1, Q3, and Q4 completed Sessions 1 and 2 on the same day. Q3 and Q4 had 1 day between Sessions 2 and 3, whereas Q4 had 4 days between Sessions 2 and 3. Q5 had 1 day between Sessions 1 and 2, and 6 days between Sessions 2 and 3.

*Trial structure.* All trials used a zero-delayed matching-to-sample task. A trial began with the presentation of a sample stimulus. A left mouse click within the stimulus area resulted in the removal of the sample stimulus and the immediate presentation of comparison stimuli. Comparison stimuli remained visible for 3 s. During this 3 s, a mouse click had no effect. After the 3 s had timed out, a click on any comparison resulted in the immediate removal of all comparison stimuli and the presentation of feedback. The stimulus-pairing duration was not signalled by additional stimulus cues. Correct and incorrect responses were followed by the appropriate feedback stimulus. A click on the feedback stimulus resulted in its removal 1 s later, followed by a 1-s intertrial interval, after which the next trial began.

*Parts 1 and 4: Instructions and baseline training (Part 1) and overtraining (Part 4).* Before the

first session, participants were presented with the following instructions on the computer screen:

“Welcome. In this experiment you will be shown a number of kanji characters. Your task is to learn which kanji go together. In a single trial, a kanji will appear in the center of the screen. Click the kanji to make another three kanji appear below. After 3 seconds you will be allowed to choose a kanji to go with the first one.  
You will be given feedback about your choice. To begin with, you will have to guess, so you will get about 1 in 3 correct. As you progress through the experiment though, you will learn which kanji go together, and you will get more correct.  
At certain points in the experiment different trials will appear and you will receive no feedback for your choices.  
Answer these trials as correctly as possible. More instructions will appear later in the experiment.”

A many-to-one (Ax-Bx, Cx-Bx) training structure was used such that three 3-member classes were expected to emerge from baseline training. Class-specific incorrect comparison stimuli were arranged such that on Class 1 trials, the correct comparison B1 was always

presented with G1 and H1, and so on. B1, B2, and B3 never appeared together as comparisons during baseline training. Feedback was presented on every trial in Part 1.

Training was conducted in blocks of 36 trials. For each block, trials were sampled without replacement from all possible combinations of class (1, 2, or 3), sample (A or C), and locations of the comparison stimuli. One block contained three trials of each relation (e.g., A1-B1). The correct comparison was presented equally across the comparison positions within a block. Part 1 continued until responding was at least 85% correct in two consecutive training blocks. When this criterion was reached participants were given the following instructions:

"The experiment will continue but you will now receive no feedback.  
Feedback may appear later. Take a break and click to continue."

A mouse click to the instruction text advanced the experiment to Part 2.

*Parts 2 and 5: Removal of feedback and baseline maintenance.* All feedback was removed in Part 2. Selection of a comparison stimulus was, therefore, immediately followed by the 1-s intertrial interval. The block structure in Part 2 was as for Part 1. In order to progress to testing, responding had to be maintained at 85% correct in one block of trials. No instructions were given prior to testing. However, if the performance criterion for baseline maintenance was not satisfied, the participant was presented with the following instructions:

"The experiment will continue but you will now receive feedback.  
Take a break and click to continue."

A response to the instruction text was followed by a repeat of Part 1. All conditions for advancement of the procedure remained.

*Part 3: Equivalence testing.* Tests for symmetrical relations (Bx-Ax, Bx-Cx), and combined symmetrical and transitive stimulus relations (combined trials; Ax-Cx, Cx-Ax) were conducted. On all test trials throughout the experiment, the comparison stimuli were the three letter-identified stimuli, one from each class. A test trial for Bx-Ax emergent relations, for example, might present B1 as the sample and A1, A2, and A3 as the comparison stimuli. The test block contained 72 trials and consisted

of 36 baseline trials, 18 symmetry trials, and 18 combined trials. Baseline trials were sampled as for Part 1, and no feedback was given on any trials in Part 3. Three trials of each symmetry and combined relation were randomly sampled without replacement from all possible sample-comparison combinations. Trials testing symmetrical, and combined equivalence, relations were mixed with baseline trials and presented in a pseudorandom order. The criterion for maintenance of baseline relations was set at 85% correct during Part 3 testing and was assessed upon completion of an entire test block. If this criterion was not met, instructions that feedback was to be implemented again (see Part 2) were presented, and the Part 1 procedure was reintroduced. The criterion for the completion of Part 3 was set at 85% correct across both baseline and equivalence test trials. If the criterion was not met, participants were returned to Part 1. Progression to Part 3 was as described above. The first experimental session ended after completion of Part 3, or after 1.5 hr, whichever occurred first.

*Part 6: Correlation-based stimulus class testing.* Tests for stimulus classes based on stimulus pairings involved the following trials: Ax-Gx (e.g., A1 as sample, G1, G2, and G3 as comparisons), Bx-Gx, Cx-Gx, Ax-Hx, Bx-Hx, Cx-Hx, Gx-Hx, and the reverse of each. The test block contained 198 trials and consisted of 72 baseline trials and 126 test trials. Baseline trials were sampled as in Part 1. Three trials of each test relation were randomly sampled without replacement from all possible sample-comparison combinations. The class-consistent comparison appeared in each comparison position once. Test trials were mixed with baseline trials and presented in a random order. No criterion for progression was set during Part 6 testing, because the experiment ended upon completion of Part 6.

## RESULTS

Figure 4 shows acquisition of Classes 1 to 3 baseline relations where percent correct is plotted as a function of the number of training blocks (including Part 2) for each class. The number of training blocks required to reach the criterion for progression to Part 2 ranged from three to five. There were no systematic differences between the three acquisition

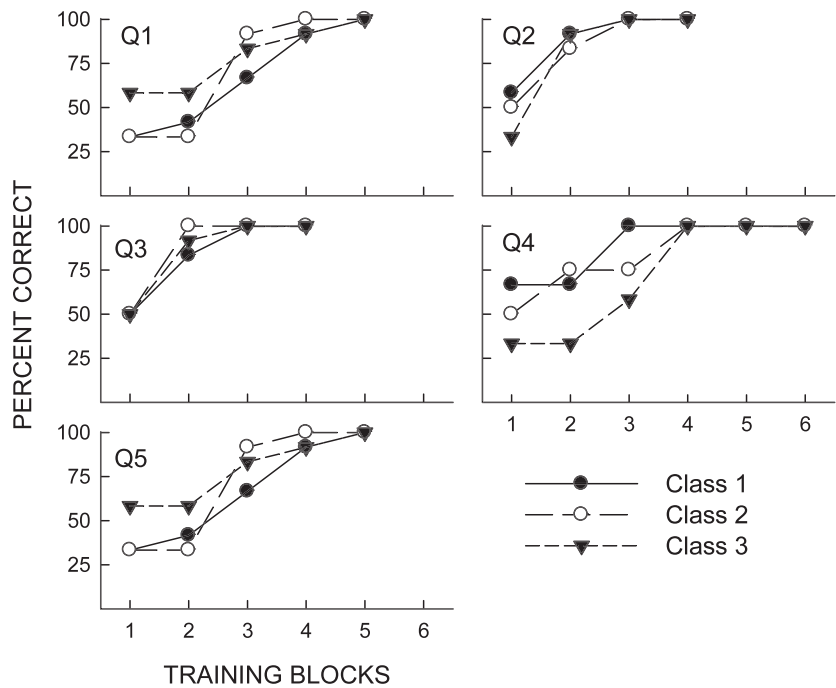


Fig. 4. Percent correct for each participant on Classes 1 to 3 stimulus relations for all Parts 1 and 2 training blocks in Session 1. Part 2 accuracies are shown with the rightmost data point.

functions across participants, suggesting that our failure to counterbalance stimuli across classes had no systematic effect. All participants responded at 100% correct across all classes during Part 2.

Figure 5 shows percent correct on Part 3 baseline and equivalence test trials. All participants maintained 100% correct across all baseline trials with the exception of Q3 and Q4 who made one error on Class 1 baseline maintenance trials. Data from symmetry and combined trials are pooled together and presented as equivalence tests. All participants responded at 100% correct on equivalence tests across all classes. All participants responded at 100% correct during Part 4 baseline overtraining in Sessions 2 and 3, with the exception of Q4 and Q5 who each made one error during Session 2, and Q2 who made one error during Session 3 overtraining (data are not shown).

Figure 6 shows percent correct on Part 6 baseline trials and correlation-based test trials, assessing the emergence of stimulus classes consistent with the stimulus pairings that occurred on baseline trials during comparison

presentation. Percent correct in this figure refers to selection of the class-consistent stimulus. The criterion for the emergence of stimulus classes consistent with the comparison stimulus pairings was set at 85% correct for each class. Figure 6 shows that 4 of 5 participants (Q1 to Q4) scored above 85% correct on test trials for all classes, indicating that the training procedures were sufficient to produce the emergence of common stimulus functions based on the stimulus correlations of comparison presentation, and independent of the reinforcement contingencies. Q5 failed to meet the 85% criterion for any of the stimulus classes. An analysis of Q5's data showed a lack of control by stimulus relations based on comparison stimulus pairings with the exception of Class 3 G–H and H–G relations. Q5 also consistently chose the Class 1 comparison on Class 2 B–H and H–B trials (see Appendix).

DISCUSSION

Our results indicate that reinforcement contingencies are not a necessary condition



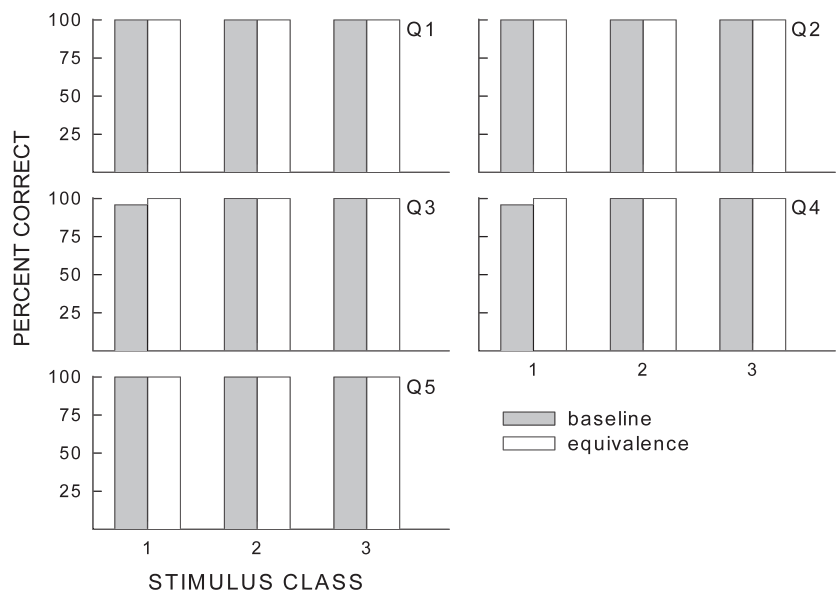


Fig. 5. Percent correct for each participant on Part 3 baseline trials and equivalence tests (symmetry, and combined symmetry and transitivity) for all stimulus classes.

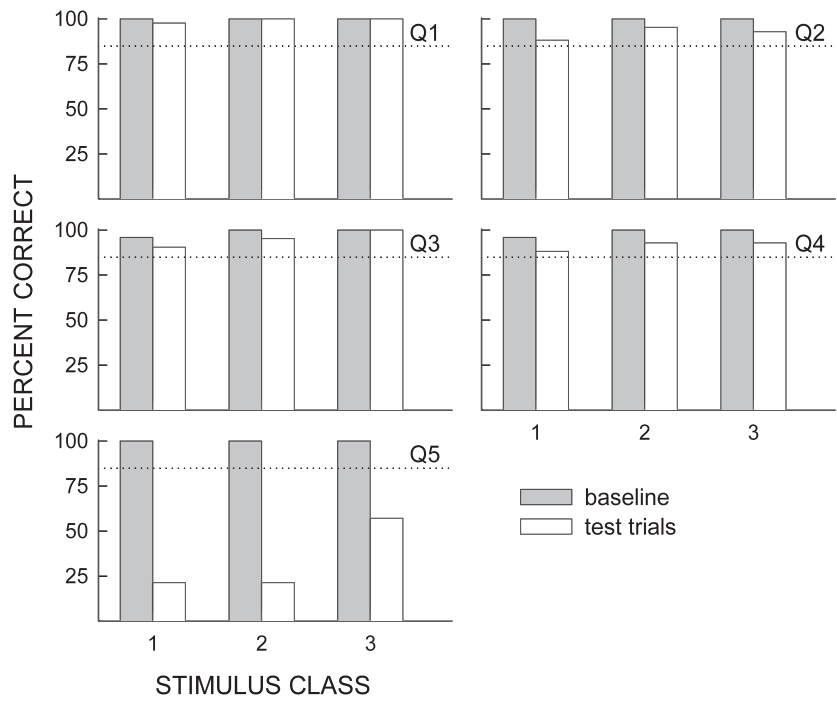


Fig. 6. Percent correct responses for each participant on Part 6 baseline and test trials (A-G, A-H, B-G, B-H, C-G, C-H, G-A, G-B, G-C, G-H, H-A, H-B, and H-C) for stimulus classes based on comparison-stimulus pairings. The 85% criterion for the emergence of these classes is shown on each graph as a dotted line.

for the establishment of common stimulus functions (i.e., stimulus classes). Environmental stimulus correlations alone were a sufficient condition for the emergence of behavioral matching relations consistent with such correlations, and these environmental correlations overrode any behavioral matching relations established through reinforcement contingencies. This was demonstrated in 4 of 5 participants with the emergence of common stimulus functions among stimuli that had a consistent environmental correlation, but between which behavioral matching relations had been explicitly not reinforced. This last point is critical—the stimulus relations that emerged had not simply had no history of reinforcement, so that they might have been predicted to be relatively neutral. More strongly, they were relations that either had an explicit history of extinction (e.g., Ax–Gx) when the participants learned the baseline discrimination, or could only have been derived from a common environmental correlation of their members with an explicitly extinguished relation (e.g., Gx–Hx relations).

At least in our procedure, environmental correlations apparently played a more fundamental role than did operant reinforcement or extinction in influencing stimulus matching and the development of common stimulus and response functions. Our data therefore support Tonneau's (2001, 2002) suggestion that stimulus correlations work independently of operant reinforcement variables to influence the development of common stimulus functions. This finding also supports the conclusions of Minster *et al.* (2006)—an account of stimulus equivalence, or of the emergence of common stimulus functions and function transfer, based solely on reinforcement contingencies (e.g., Sidman, 2000), cannot predict the behavior seen in these experiments. The parsimonious interpretation is therefore that stimulus correlations, rather than reinforcement contingencies, may have been responsible for the emergence of common stimulus functions, and Sidman-type equivalence, in Part 3 as well. This interpretation, we suggest, can also be applied to previous experiments reporting Sidman equivalence.

We used class-specific incorrect comparisons to establish an environmental relation between comparisons and their associated reinforcement-contingency-related stimuli. This is

not typical of conditional discrimination tasks, and was arranged to ensure that incorrect comparisons did not participate in any environmental relations with stimuli from other classes. In fact, the use of class-specific incorrect comparisons effectively means the baseline tasks of the present experiments were not conditional discriminations as traditionally defined (e.g., Cumming & Berryman, 1965; Sidman, 1986). Participants did not have to respond to Bx comparisons conditionally upon the sample; they simply had to respond to Bx. But this does not mean the baseline tasks of the present study can be reduced to a simple discrimination of  $Bx^+$  from  $Gx^-$ ,  $Hx^-$ . If the participants' responses were controlled by a simple discrimination of this type, we would not expect to see the emergence of equivalence relations, or matching relations between the Ax and Cx samples that preceded Bx stimuli. Indeed, there would be no reason to expect any attention to, or control by, Ax and Cx. Yet the results of the equivalence tests showed the emergence of relations between Ax and Cx stimuli, and these would not be possible if baseline training had not also established matching relations between Samples Ax and Cx, and Comparison Bx. Because of the development of Ax–Bx and Cx–Bx matching relations, which must have arisen through contact with the reinforcement contingencies, we must also assume that, through contact with the reinforcement contingencies, Ax–Gx, Ax–Hx, Cx–Gx, and Cx–Hx nonmatching relations also developed (because participants contacted contingencies for both matching and nonmatching relations, it seems unparsimonious to argue for the development of one type of relation and not the other). Despite there being nonmatching relations between samples, and incorrect comparisons (established through the reinforcement contingencies), responding on correlation-based tests showed the emergence of matching relations between these same stimuli, when the only previously existing relation between them was of nonmatching. That is, we observed the emergence of a behavior that was in the opposite direction to that predicted by the reinforcement contingencies. This suggests that the role of reinforcement in emergent stimulus relations is less central than previously supposed (e.g., Sidman, 2000; RFT in general) and supports L. Hayes' (1992) and

Tonneau's (2001, 2002) emphasis on the role of stimulus correlation.

Interestingly, this conclusion parallels recent reevaluations of the role of reinforcement in concurrent schedules (e.g., Davison & Baum, 2006; 2007; Krägeloh, Davison, & Elliffe, 2005) and of the mechanism underlying secondary or conditional reinforcement (e.g., Boutros, Davison, & Elliffe, 2009; Shahan, 2010) and perhaps also primary reinforcement (Davison & Baum, 2007; Shahan, 2010; Shahan & Podlesnik, 2005; see also Baum, 1973). These views place less emphasis on the direct instrumental effects of reinforcement—that it strengthens a response that it follows—and stresses the signalling, or stimulus, effects of reinforcement (see also Gallistel & Gibbon, 2002). In our results, "reinforcers" again acted as guides, discriminative stimuli, or signposts for conditional discrimination. At least in the correlation-based test trials, the absence of reinforcement apparently did not weaken the response (selecting Gx or Hx) that preceded that absence, and reinforcement did not strengthen the response (selecting Bx) that did produce reinforcement. As in the reappraisals of reinforcement contingencies noted above, our data seem best understood by considering reinforcers as stimuli like any other in the environmental path, in Tonneau's (2001) terms, with no special status as direct strengtheners of behavior.

The pilot study for the present experiment did not reliably produce the emergence of the correlation-based matching relations seen in the present experiment. Some participants even failed to show the emergence of the standard, traditionally regarded as contingency-based, equivalence relations. We might have tried to enhance the emergence of these standard relations by increasing the efficacy of the reinforcer. Instead, we increased the amount of overtraining, and we saw the emergence both of more consistent contingency-based (Part 3), and of correlation-based (Part 6) relations. The use of overtraining is not common practice in stimulus equivalence experiments, and raises some issues regarding the strength of the conclusions with respect to contingency-based theories.

Certainly our use of conditional reinforcers, which might have less capacity to maintain behavior than primary reinforcers, is commonplace in equivalence studies. These stimuli

clearly did act as reinforcers, because our participants learned the baseline conditional discriminations. Still, the question of what might have happened were more salient, or more effective, reinforcers arranged remains to be answered. Surely, it should be possible to manipulate the amount of control by reinforcement contingency versus stimulus correlation by changing the reinforcer. For example, if a very large monetary reinforcer were used, we would predict that attention to the reinforcer would increase, and therefore that the emergence of reinforcement-based stimulus relations would be more likely.

Perhaps if a more salient reinforcer was used, the amount of overtraining would have to be increased further to see the effects of correlation overriding contingencies. This suggestion, that we might titrate the effects of overtraining for the emergence of correlation-based effects depending on the strength of the reinforcer, is a clue that contingencies and correlations operate simultaneously, and that under certain conditions the effects of reinforcement contingencies will dominate, while under other conditions the effects due to correlations will be obvious—it is the job of the experimenter to define such conditions. The message of this experiment is that a reinforcement contingency which was effective enough to produce accurate baseline performance nevertheless did not produce emergent relations that could survive the challenge of being brought into conflict with emergent relations due to stimulus correlation.

One factor that likely plays a part in determining what stimulus functions are expressed is the stimulus array. In the present experiment, it may be argued that conditions were geared towards the emergence of matching relations involving class-specific  $S^-$  stimuli as the comparison array presented only  $S^-$  stimuli. It would have been interesting to see what behavior we would have seen had we arranged, for example, a "none-of-these" response option. A comparison array containing  $S^-$  stimuli and an  $S^+$  stimulus from a different class from the sample (e.g., A1 as sample, G1, G2, and B2 as comparisons) would also be of interest to test. In this case, would correlation override an  $S^+$  function, and under what conditions? Would testing of the more traditional equivalence relations have to occur first in order to distinguish the classes of  $S^+$

stimuli? Or what effects would we see if all tests were presented in a single block? There are clearly more experiments to be carried out to investigate the conditions that sway the effects of reinforcement and those of correlations.

#### *Implications for Theoretical Accounts of Equivalence*

An RFT account of the emergence of common stimulus functions among Ax, Bx, Cx, Gx, and Hx would interpret responding on correlation-based test trials as evidence for a generalized response class; the frame of coordination. This account argues that participants who are members of the verbal community are taught, through contact with reinforcement contingencies, that events that are temporally and/or spatially correlated “go together” or form equivalence relations. After a sufficient history of forming equivalence relations between stimuli that are temporally and spatially correlated, the response of forming equivalence relations then generalizes to correlated stimuli between which the relation of equivalence has never been explicitly reinforced, given an appropriate context for such generalization to occur (e.g., Leader *et al.*, 1996, p. 703). Responding by participants on the correlation-based test trials, where stimuli that appeared together on a particular trial, but were explicitly not associated by reinforcement, is therefore viewed as exemplifying a generalized response class (the frame of coordination) which has arisen because all the participants had a history of placing in a frame of coordination stimulus events that are temporally and spatially correlated.

One problem with an RFT-based account of the present data that relies on the generalization of a response class is that, at some point in a participant’s history, the emergence of a common stimulus function must have occurred through some process, and was then reinforced after this initial emergence, thereby increasing the rate at which it occurred under certain conditions. But appealing to a history of reinforcement for the emergence of common stimulus functions does not explain why this phenomenon occurred in the first place, before it was ever reinforced (see e.g., Tonneau, 2001, pp. 120–121; Tonneau & González, 2004, p. 252). In the absence of reinforcement, some other factor must underlie the emergence of common stimulus functions,

and that factor is likely to be stimulus correlations. Moreover, it is quite unclear why, from an RFT perspective, relations based on stimulus correlations should override those based on reinforcement when the two kinds of relations conflict, as happened here. Perhaps the most serious problem the present data pose for RFT is that the establishment of the relational frame of coordination is, in that theory, supposed to originate from a history of reinforcement for behavioral matching relations between certain stimuli. How such a history would then give rise to a response class that generalizes to stimuli for which the behavioral matching relation has been explicitly (negatively) punished (i.e., the exact opposite behavior to that which established the response class) is unclear, and illustrates Palmer’s (2004) criticism of RFT as having stretched the “notion of a topographically heterogeneous class beyond its limits” (p. 227).

A correlation-based account (Tonneau, 2001, 2002) of our results would regard environmental stimulus pairings as a sufficient condition for stimulus matching when participants have an established history of identity matching. Tonneau’s account uses the concept of a temporally extended environmental path whose properties can influence responding when the actual stimuli are no longer physically present. In this environmental path, successive states are defined cumulatively so that if an organism and its path are in state A, and the organism is successively shown the stimuli B, C, and D, the organism’s environmental path moves through the states A, AB, ABC, and ABCD (not A, B, C, then D). While the presentation of a stimulus, B, is indeed a discrete event (stimulus B appears and disappears), as time passes and the organism’s environmental path is extended, B is still a property of the environmental path. Because B is still present in the environmental path it may therefore influence responding if current environmental events have previously been correlated with B (see Tonneau, 2001, pp. 21–25).

In our experiment, the repeated correlation of (for example) A1, B1, G1, and H1 that occurred on baseline trials meant that at the later stage of correlation-based testing, the presentation of A1 as a sample reestablished control by the correlated stimuli B1, G1, and

H1, which were still present as properties of the environmental path. According to Tonneau's (2001, 2001) account, if G1 was present as one of the comparison stimuli, the presence of G1 (as a path property potentiated by Sample A1) and a history of matching the same or similar events, would result in the emergence of A1–G1 matching as a form of identity matching across time (of {A1, G1} to G1, from the environmental path property to the present comparison choice). Note, however, that this explanation requires that stimulus pairings involving incorrect comparisons and a given sample can also become part of the environmental path. This point is somewhat obscure in Tonneau's writing where "The argument applies more strongly to correct comparisons... than to incorrect ones. Although all *nominal* (emphasis original) stimuli are equally correlated with one another, *the participant's matching particular stimuli favors these pairs over the others* (emphasis added) in a correlation-based process." (Tonneau, 2001, p. 121, footnote 10).

An account based on L. Hayes' (1992) interpretation of stimulus equivalence as a form of indirect reflexivity or identity matching is similar to Tonneau's. Her account asserts that the functions (e.g., perceptual functions) of one stimulus may be indirectly acquired by another stimulus if those two stimuli have an historical spatiotemporal correlation. The indirectly acquired perceptual functions may then actualize response functions of the first stimulus, resulting in the emergence of novel stimulus functions with respect to the second stimulus. In the present experiment, the consistent spatiotemporal correlation between Sample A1 and Comparisons B1, G1, and H1 should eventually result in the indirect acquisition of the perceptual functions of B1, G1, and H1 with respect to A1 (i.e., A1[B1, G1, H1], where the bracketed terms refer to specific indirect stimulus functions occurring with respect to the first term). On a correlation-based A1–G1 test trial, for example, the selection of G1 and not G2 or G3 is due to the indirect functions of G1 occurring with respect to A1, resulting in a form of indirect identity matching (i.e., matching A1[G1] to G1). As with Tonneau's correlation-based account, an account based on L. Hayes' position must make some allowance for the eventual indirect acquisition

of stimulus functions between stimuli whose behavioral matching relation has been explicitly not reinforced, but between which there stands a consistent environmental correlation. The presentation of a reinforcing stimulus might "serve to strengthen only particular stimulus–stimulus relations" (Rehfeldt & Hayes, 1998, p. 201), but it seems such an effect is transient in the sense that any stimulus correlations can eventually control responding and result in the emergence of novel stimulus functions.

It is important to note that all the theories discussed above share a reluctance to make specific a priori predictions about what will, and will not, occur given a particular set of conditions. Relational frame theory, Tonneau's (2001, 2002) correlation-based account, and L. Hayes' (1992) indirect-reflexivity account are all capable of dealing with any data set, including ours, after these data are obtained, and it is with respect to the lack of a priori predictive power and the flexibility of an a posteriori interpretation of any data set that all three positions appear to be unfalsifiable. Specifically, each position can interpret the emergence of stimulus relations involving class-specific incorrect stimuli, but it does not seem to us that any of them explicitly predicts that such relations will, after overtraining, override the stimulus relations derived from the operant contingencies.

#### *Operant and "Respondent-type" Contingencies*

That reinforcement contingencies and stimulus correlations can produce the same outcomes, such as the emergence of common stimulus functions, has led some to question the distinction between operant and respondent processes (e.g., Donahoe, Palmer & Burgos, 1997; Rehfeldt & Hayes, 1998). When reinforcement contingencies are arranged, they necessarily also involve stimulus correlations (e.g., Tonneau, 2001, 2002), so it may be that correlations are the fundamental driving force for the organization of behavior. Donahoe et al. also argue that there is no way to distinguish between operant and respondent procedures from the organism's perspective. Rather, the distinction between operant and respondent conditioning reflects confusion between the behavior of the experimenter with that of the experience of the organism. In the operant paradigm, the organism is always



contacting environmental stimuli before reinforcer delivery so that relations may emerge between stimuli, responses, and reinforcers, in a way that resembles respondent stimulus relations, even though these stimuli may not participate in the experimenter-defined contingencies of reinforcement. Similarly, in the respondent paradigm, the organism is always behaving in some manner before the introduction of an unconditioned stimulus in a way that resembles operant response–reinforcer relations, even though the presentation of the unconditioned stimulus is not contingent upon the emission of such responses. Because an organism is always responding in its environment, and environmental events are always contiguous with responding, relations will always exist between stimuli and other stimuli, and between responses and stimuli, regardless of the experimentally-arranged contingencies. In a single instance, there is no way to distinguish between operant and respondent procedures.

It seems a parsimonious working assumption that reinforcement has no unique and qualitatively different status—rather, it is an environmental event which may or may not be correlated with other events and with behaviors. It is likely to be a powerful event, especially if of large magnitude, high salience, or strong biological significance to the organism. To the extent that it is correlated, it will lead to the emergence of novel stimulus relations. Correlations with reinforcement are likely to dominate over other environmental correlations, especially early in training, and this may be handled in terms of differential weighting in a theory of emergent relations. However, the difference is one of degree, rather than of kind, and so it is possible that other correlations will eventually come to dominate, given sufficient exposure, as in the present data.

### *Exclusion*

Finally, our data speak to the phenomenon of *exclusion* in matching-to-sample tasks. Exclusion refers to the possibility that accurate matching-to-sample performance may be partly due to the participant eliminating incorrect comparison stimuli as well as selecting the correct comparison stimulus. The use of an exclusion strategy seems to be possible for a variety of species and kinds of human partic-

ipant, including normal adult humans (e.g., McIlvane, Kledaras, Munson, King, de Rose, & Stoddard, 1987; Meehan, 1995; Stromer, 1989) and adults with mental retardation (e.g., Dixon, 1977), children with (e.g., McIlvane, Kledaras, Lowry, & Stoddard, 1992; McIlvane & Stoddard, 1981) and without (e.g., McIlvane, Munson, & Stoddard, 1988; Stromer, 1989) mental retardation, chimpanzees (e.g., Beran & Washburn, 2002; Tomonaga, 1993), and sealions (Schusterman, Gisinier, Grimm, & Hanggi, 1993), although not yet for pigeons (e.g., Cumming & Berryman, 1961; but see Zentall, Edwards, Moore, & Hogan, 1981).

In our experiment, an exclusion strategy would have predicted that on, for example, an A1–Gx test trial, G1 would have been eliminated because it is explicitly incorrect after an A1 sample, and choice would have been indifferent between G2 and G3. This clearly did not happen in our experiment. There are two implications: First, the traditional insistence on controlling for the possibility of exclusion in, for example, attempts to demonstrate equivalence relations in animal participants may be less critical than has been supposed. Second, exclusion may be less to do with ruling out a comparison stimulus because it is incorrect for the current sample than with ruling it out because it is correct for a different sample. This interpretation could explain the lack of exclusion in our experiment, since the Gx and Hx comparison stimuli were not correct comparisons following a different sample stimulus. An experiment testing that possibility is about to begin.

## CONCLUSION

The present study adds to our understanding of the variables underlying the development of common functions, and of learning in general: Environmental stimulus correlations are the fundamental influence on learning, not reinforcement contingencies. Our data support this view by demonstrating common stimulus functions based on stimulus correlations that were directly opposed to functions that were established through reinforcement. As in recent conceptions of the mechanism of reinforcement in choice, the central role of reinforcement in emergent stimulus relations needs to be reconsidered.

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APPENDIX

The number of times Participant Q5 in Part 6 chose a comparison stimulus from each class on each type of test trial and following sample stimuli from each class.

Sample class	Comparison class	BG	GB	BH	HB	AG	GA	AH	HA	CG	GC	CH	HC	GH	HG
1	1	1	—	—	—	2	1	1	—	2	—	—	—	1	1
	2	—	—	2	3	—	—	—	3	1	2	2	2	1	—
	3	2	3	1	—	1	2	2	—	—	1	1	1	1	2
2	1	—	2	3	3	1	—	2	1	2	—	2	—	2	—
	2	3	1	—	—	—	3	—	—	—	2	—	—	—	—
	3	—	—	—	—	2	—	1	2	1	1	1	3	1	3
7	1	2	2	1	1	—	2	2	—	—	2	—	2	—	—
	2	—	—	—	—	—	1	—	1	1	1	—	—	—	—
	3	1	1	2	2	3	—	1	2	2	—	3	1	3	3